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[COMMITTEE PRINT]

TITANIUM

STAFF REPORT

SPECIAL SUBCOMMITTEE ON MINERALS,
MATERIALS, AND FUELS ECONOMICS

OF THE

COMMITTEE ON
INTERIOR AND INSULAR AFFAIRS
UNITED STATES SENATE
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FOREWORD

AUGUST 16, 1955.

To the Members of the Senate Interior and Insular Affairs Committee:

Because of the confusion surrounding the titanium program I ordered a detailed study by the staff of the Subcommittee on Minerals, Materials, and Fuels which is printed herein and which I am sure will be of the greatest interest to you, to the industry and to the Government agencies involved.

I further have instructed the staff to make continuing studies, issue such supplementary reports as may be required, and prepare for possible future public hearings.

I heartily concur in the conclusions reached by the subcommittee staff, which operated with the advice and counsel of former Maj. Gen. Kern D. Metzger, USAF, retired, now deceased, who was widely acknowledged to be the outstanding authority in this field. The careful and detailed direction of General Metzger was invaluable. I also wish to commend my personal consultant on minerals and metals, Bill Broadgate, and subcommittee staff members Robert W. Redwine and George B. Holderer for their devoted attention to the task I set for them.

I feel sure this staff report and the additional work to be done will help to clarify in the minds of industry and the public the future of this important strategic metal.

JAMES E. MURRAY, *Chairman.*

TITANIUM

Introductory

From the testimony of witnesses before various congressional committees, items in the press and the actions of various Government agencies concerned with the titanium expansion program, it has become increasingly apparent that large areas of confusion and a startling lack of coordination exist which have made a smoothly operating integrated program difficult of accomplishment.

IMPORTANCE TO NATIONAL DEFENSE

That titanium is an important metal in the national-defense picture is indisputable. Titanium, and the extent to which it is used in military aircraft, may make the difference between victory and defeat in case of war.

With this in mind, Senator James E. Murray, chairman of the Senate Committee on Interior and Insular Affairs and the Subcommittee on Minerals, Materials, and Fuels, ordered an intensive staff study and report to be made under the direction of Maj. Gen. Kern D. Metzger, United States Air Force (retired), a widely acknowledged authority in the field of titanium, especially in its utilization in military aircraft. To this end an extensive series of off-the-record conferences were held with sponge producers, fabricators, end users, and Government officials concerned with requirements planning, development and research, and expansion programs, with all but a few of the conferences being held under the chairmanship of General Metzger.

CONFERENCE CONDITIONS

In order to provide an atmosphere of free and unreserved discussion no stenographic record was made, though it was permitted that staff members and the persons being interviewed might make whatever notes they pleased. Immediately after each meeting the staff notes were assembled into confidential staff memorandums "for the file." Each conference was set up so as to stand on its own base, and there was little or no reference with any one group as to what had been discussed with another. Questions were asked freely on all sides and, because of the informality and the feeling of mutual confidence so engendered, the answers appeared to the staff to be given without reservation. As the conferences continued their effectiveness became more and more apparent, it being evident that a developing spirit and pattern of intercommunication between those interviewed was beginning to result in clearing up some of the difficulties which General Metzger and the staff had earlier detected as holding back realistic usage of this vitally needed new metal.

Senator Murray ordered this interim staff report printed with the idea that the conclusions drawn by the subcommittee staff may later

on be the subject of testimony at public hearings. Each person or group interviewed was informed that, should he or they be invited to testify before the subcommittee the questioning would be designed to cover approximately the same area as discussed during the conferences.

The subcommittee staff believes that this report represents a fair and impartial presentation of the information exhaustively delineated to it during the course of the interviews.

LIST OF WITNESSES ATTENDING

Mr. Harold S. Vance, titanium consultant to the Office of Defense Mobilization, attended one session with the subcommittee staff at the beginning of the series and attended one conference. General Metzger invited Mr. Vance to sit in through the entire series but he did not take advantage of the opportunity.

Certain additional conferences were held by General Metzger in the field on a semipersonal basis. One conference was set up by General Metzger at the Allison Division, General Motors Corp., in Indianapolis, with more than 10 members of the technical staff of that corporation. Due to the unfortunate death of General Metzger just prior to this meeting it was covered by the subcommittee staff engineer, George B. Holderer, who submitted a complete report upon it.

From 1 to 4 representatives of each industrial concern or Government agency attended the various conferences. The people and organizations interviewed included:

WITNESSES APPEARING AT TITANIUM CONFERENCES, APRIL 22–JUNE 23, 1955

GOVERNMENT AGENCIES

Office of Defense Mobilization	
Apr. 22, 1955	Harold Vance, consultant on titanium.
May 9, 1955	James P. Durkin, Assistant General Counsel.
	Edwin Harris, commodity industry analyst.
	William N. Lawrence, industry specialist.
Department of Defense	
Apr. 28, 1955	Carl Rolle, chief, Materials Branch, Requirements, Review and Analysis Division, Office of Assistant Secretary of Defense (Supply and Logistics).
	Dr. Timothy May, commodity specialist, Office of Assistant Secretary of Defense (Supply and Logistics).
Apr. 29 and May 26, 1955.	John Garrett, executive secretary, Coordinating Committee on Materials, Office of Assistant Secretary of Defense (Research and Development).
	Frank L. Toy, consultant to Committee on Materials, Office of Assistant Secretary of Defense (Research and Development).
May 26, 1955	Col. Benjamin S. Mesick, United States Army (retired), consultant.
Department of Air Force	
June 16, 1955	Col. Wilbur Carter, chief, Industrial Resources Division, Directorate of Procurement and Production, Office of Deputy Chief of Staff (Materials).
	Col. Thomas Ardis, chief, Resources Branch, Industrial Resources Division, Directorate of Procurement and Production, Air Materiel Command, Wright Patterson Air Force Base.
	Col. Henry G. McDonald, chief, Production and Resources Division, Air Materiel Command, Wright Patterson Air Force Base.

Department of Army

June 14, 1955 — E. L. Holladay, research and development, Watertown Arsenal, Watertown, Mass.

Department of Navy

June 15, 1955 — N. E. Promisel, head, Materials Branch, Bureau of Aeronautics.

General Services Administration

June 23, 1955 — A. J. Walsh, Commissioner, Emergency Procurement Service.
I. E. Weber, Expansion Material Division.

AIRCRAFT COMPANIES

Apr. 27, 1955 — Convair division of General Dynamics (Fort Worth Division):
B. G. Reed, assistant director.
L. G. Monroe, project officer.

May 19, 1955 — Curtiss-Wright Corp. Herman Hanink, chief metallurgist.

June 1, 1955 — General Electric Co., aircraft gas turbine division:
Dale Streid, manager of engineering, jet engine department.
George Wile.

May 25, 1955 — General Motors Corp., Allison division:
E. Berlin, head, experimental materials and processes.
A. W. F. Green, technical assistant to executive engineer.

June 22 and June 23, 1955 (visit to Indianapolis plant). — General Motors Corp., Allison division:
T. S. McCrae, executive engineer, production functions.
R. E. Settle, executive engineer, administrative functions.
C. T. McDowall, chief engineer, advanced design and development.
J. C. Fetters, chief engineer, turbo-prop engines.
C. Hockert, chief engineer, turbo-jet engines.
J. L. Goldthwaite, technical assistant to engineering assistant to general manager.
E. Berlin, head, experimental materials and processes.
R. Heller, project engineer, critical materials, turbo-prop engines.
D. Hanink, chief metallurgist.
A. W. F. Green, technical assistant to executive engineer.

May 18, 1955 — Grumman Aircraft Co.: Ira Hedrick.

June 2, 1955 — North American Aviation, Inc.:
Dr. N. F. Parker, assistant section chief, systems, guidance section.
L. P. Spalding, chief research engineer.
Allen Andrews, staff assistant, Washington office.

May 24, 1955 — Pratt Whitney Aircraft Co., R. H. Thielemann, development metallurgist.

May 17, 1955 — Republic Aviation Corp.:
Wm. J. O'Donnell, chief of developments.
Harry George, metallurgist, manufacture, research, and development.

FABRICATING COMPANIES

May 12, 1955 — Mallory-Sharon Titanium Corp.: James A. Roemer, president.

May 11, 1955 — Rem-Cru Titanium, Inc. (subsidiary of Crucible Steel Company of America):
C. I. Bradford, vice president.
E. J. Mechlin, Jr., branch manager, Washington office.

MISCELLANEOUS

May 16, 1955..... Aircraft Industries Association: Victor Mellquist.
May 10, 1955..... Chicago Development Corp.: Dr. Reginald S. Dean, consulting engineer.
June 21, 1955..... Metal Hydrides, Inc.: Messrs. Gordon, Landers, O'Donnell, and McClintock.
June 16, 1955..... Western Pyromet Corp.: George Miller.

Research and Development

POSSIBILITY OF LOWERED COSTS

The subcommittee staff concluded that although a fairly good job has been done to date in stimulating the development of new processes, such as variations of the Kroll process, every effort should be made to intensify this work with the particular end in view of lowering the cost of sponge production, and effecting greater scrap recovery. It seems probable that a substantial decrease in cost may only be accomplished through the development of radically different processes such as the production of titanium powder or metal on a continuous scale rather than by batch production.

As the cost bottleneck of most processes appears to rest largely upon the price of titanium tetrachloride it might be well to turn a searching eye on this problem.

Further, an even greater total cost reduction in the final mill product will come from integration of all operations from ore reduction to manufacture of mill products. The cost savings resulting from integrating operations and developing specialized mill equipment designed for titanium is passed on through lower priced mill products to fabricators and end users. The dollar value of recent reductions in rod, bar, extrusions, forgings, and sheet is greater than the total cost of sponge. Reduction in the cost of titanium mill products will do most to increase use of titanium.

MORE GOVERNMENT AID INDICATED

The Government should not only help actively in the development of primary production processes but, the subcommittee staff feels, might well provide more aid to fabricators in evolving new methods, even to the extent of financing special equipment such as extrusion machinery, heavy presses and rolling mill equipment designed particularly for the handling of titanium.

Outlook for Increased Utilization

PESSIMISTIC ATTITUDE UNWARRANTED

The titanium program has been retarded, partly by the unnecessarily pessimistic attitude taken by certain Government officials and partly by the necessity of accelerating its technology to an unprecedented degree. At the staff conferences it was reiterated again and again that the problems involved in the use of this metal are no more serious and are of a similar nature to those which confronted the initial users of other new metals and alloys. Other metals and their alloys have had decades over which to develop, giving users plenty of time to leisurely evolve satisfactory techniques whereas the "forced

draft" program under which titanium necessarily has operated, magnified the difficulties of working with it. In spite of this, satisfactory methods of handling the constantly improving metal and its alloys rapidly are being discovered and put into practical use.

It definitely appears that research and development programs promise shortly to develop titanium alloys with physical properties superior to those presently required by the aeronautical industry, and it also appears that discouragement and pessimism regarding the substantial use of titanium in defense products is unfounded and that a breakthrough which could greatly accelerate demand is closer than has been supposed.

MUCH DATA OBSOLETE

The entire situation surrounding titanium is so fluid that much of the information available within the plants of the aeronautical industry today is obsolete and that many potential users of substantial quantities of titanium are not familiar with the fact that certain segments of the titanium fabricating industry are today in a position to furnish this metal with acceptable physical properties in adequate quantities for today's specifications requirements.

One group of experts from a large airframe manufacturer told the subcommittee staff substantially the following:

1. Great strides have been made in melting and fabricating titanium within the past 6 months.
2. Most of the technical data regarding titanium in company files which is more than 6 months old is in the main unreliable.
3. Titanium in mill forms, forged and extruded shapes, with satisfactory physical properties is now available for order.
4. The state of the titanium fabricating art at their own plant level was inadequate, misleading, and obsolete until quite recently.
5. Titanium alloys with physical properties exceeding present requirements for airframe use are in the laboratory stage and will be available for production use in the near future.
6. Purchase orders will be released shortly for titanium in substantial quantities and for extensive use in one new military airplane, resulting in a net weight saving of approximately 1,200 pounds per airplane.
7. The presently estimated requirement of 6,000 pounds rough weight of titanium per one particular type military aircraft will be increased as more experience is developed in the fabricating and machining of titanium within the manufacturer's plant.
8. Titanium can and is expected to replace steel to a substantial degree in future aircraft within certain temperature ranges with a highly beneficial weight saving.

TITANIUM A MUST

Enthusiasm for the use of titanium varied from lukewarm in one instance to almost the boiling point in another, with several users stating in effect "the enthusiasm for titanium is in direct proportion to the experience in its use. It is the coming metal, and a 'must.' "

Typical of the advanced and more experienced users of titanium,

was the manufacturer who stated that 80 percent of the structural weight of his new fighter-type aircraft will be in titanium.

SPECIALIZED FACILITIES REQUIRED

A number of the groups interviewed stressed the idea that specialized titanium facilities are required in order that quality may be substantially improved and cost reduced. The idea of completely integrated facilities to accomplish the same end was voiced frequently.

ESSENTIAL TO HIGHER PERFORMANCE AIRCRAFT

One large airframe manufacturer made the point that titanium is essential to higher performance aircraft and that present aluminum alloys will not satisfy the requirements for fashioning such airplanes. It was stressed that titanium and steel and their alloys presently offer the best solution to the problem. The statement was made that even though steel were to possess up to a 20 percent better strength-weight ratio than titanium, titanium would still be preferable rather than steel because of the advantage of its lesser weight.

TITANIUM AS A WEIGHT REDUCER

Engine manufacturers who were interviewed by the subcommittee staff showed an intense interest in titanium and were most optimistic about its use as a weight reducer. Estimates were submitted of the potential reduction in weight of various engines and the gross amounts of the metal needed per engine running all the way from a few hundred pounds to as high as 3,500 pounds, depending on the type of engine, and whether it now is in production or whether it is in such a state of planning that large quantities of titanium can be designed into it.

The subcommittee staff was informed by one manufacturer that it would make firm commitments for 1956 of at least 4 million pounds of titanium. The representatives of this company informed the staff that in their opinion titanium will play a very large part in the development of future jet engines, and they were of the opinion that the technology of the fabrication and machining of the metal has advanced to a point where titanium can and will be used in increasing quantities without great difficulties.

DROP IN PART REJECTION RATE

Every manufacturer mentioned the drop in their part rejection rate proportionate with their increased experience. It was stated, for example, that rejections of titanium turbine blades has been reduced to the extent that it now is approximately the same as for steel blades.

The optimism of engine manufacturers may be to a degree measured by the fact that one concern has spent nearly $3¾ million on research and development for the use of titanium in jet engines since 1948 and stated that titanium in substantial quantities is being designed into all their future engines.

EARLY DIFFICULTIES OVERCOME

To sum up, it appears that the early difficulties encountered in the use of titanium were no worse than those which were encountered with other new materials and alloys, but the condensed "forced draft" factor associated with the titanium program accentuated the difficulties. The early-day troubles generated a "burnt child dreads the fire" attitude, which retarded the program. This "let's wait and see" attitude appears to have been dissolved.

INCREASED DEMAND EXPECTED

From the information furnished to General Metzger and the subcommittee staff it appears that the demand for titanium will in the near future exceed all present expectations. One user alone expects to place orders by 1962 which will demand approximately one-half the presently contracted for supply of 22,500 tons of sponge per year.

SPONGE PROGRAM MAY BE INADEQUATE

It is felt that the potential demand indicated to the subcommittee staff on a conservative basis requires a careful review in the near future of the ODM 22,500-ton sponge freeze order, as it appears that from 2 to 3 years are required to put new facilities into full-scale production and it is quite likely that the demands of fabricators and end users may outstrip sponge-making facilities within that time.

There seems to be a general impression that the present production of titanium sponge is 22,500 tons per year whereas the facts are that only about 8,000 tons will be available in 1955 and the expectancy of 22,500 tons per year is not estimated to be available until 1958 as is shown in the table following.

TITANIUM SPONGE CAPACITY EXPANSION CONTRACTS

Productive capacity shown as tons of production of titanium sponge by years until capacity has reached contracted for 22,500 tons

Contract No.	Contractor	1955	1956	1957	1958
DMP-6	E. I. du Pont de Nemours & Co	[1] 3,600	[1] 3,600	[1] 3,600	[1] 3,600
(D)-12047	Titanium Metals Corporation of America	3,600	3,600	3,600	3,600
DMP-75	Cramet, Inc	800	5,750	6,000	6,000
DMP-99	Dow Chemical Co	85	915	1,800	1,800
DMP-100	Union Carbide & Carbon Co	0	2,000	7,000	7,500
	Total	8,085	15,865	22,000	22,500

[1] Du Pont's privately financed facility, 900 tons; Du Pont expansion under above contract, 2,700 tons.

STIMULATION OF USE AND FORMULATION OF REQUIREMENTS

BETTER REQUIREMENTS ESTIMATES NECESSARY

It appears to the subcommittee staff that one of the causes of alarm which visualizes the sponge program as having been pushed too rapidly, thus generating the cutback from a goal of 35,000 tons per year to the present goal of 22,500 tons (already fulfilled either by production or commitments to produce), has been a definite lag in the com-

pilation of up-to-date requirement figures by the responsible Government agencies. It also appears that far too many Government agencies, committees, and quasi-governmental bodies are concerned with the titanium program without proper coordination and direction from a central point. Differences in opinion among such groups operating without uniform top-policy guidance undoubtedly have contributed to the confusion which, in turn, has communicated itself to industry.

INDUSTRY PARTLY RESPONSIBLE FOR LAG IN TITANIUM PROGRAM

Industry itself must assume a good deal of the responsibility. It was General Metzger's considered opinion that the aircraft industry has the responsibility of forcefully presenting its needs for better materials to build better aircraft to the procuring services, to industry, and to the public at large. He further expressed his feeling that to date the aircraft industry has not fully discharged that responsibility and belief that the Aircraft Industries Association should formulate an energetic program to make known the aircraft industry needs, materialwise and otherwise, for the manufacture of improved military aircraft. The subcommittee staff was shocked to be told that, at the time of the particular conference, the association had not even taken a look at the titanium situation for 6 or 8 months.

NO SOUND BASIS FOR ESTABLISHING GOALS

The subcommittee staff was given to understand by representatives of the responsible Government agency that titanium requirements, either current or on a mobilization basis were never used by the Office of Defense Mobilization as a basis for establishing the 35,000 ton per year sponge production goal. Furthermore, it appeared that as of the date of the interview, no detailed requirements based upon a mobilization program had been formulated since April of 1954. The cutback and freeze order which resulted in the new 22,500-ton goal appears to have been a purely arbitrary action.

General Metzger expressed to the subcommittee staff grave concern that the establishment of arbitrary goals, unsupported by current and mobilization requirements based upon the present state of the art within the titanium industry, the fabricating facilities, and the aircraft and engine manufacturers' plants and policies which cannot be irrefutably supported by sound reasoning and facts, can only be considered as premature and likely to inflict serious harm upon the rapidly progressing titanium industry and, perhaps, result in a setback to more widespread advantageous use of titanium in military weapons.

TITANIUM PROGRAM LACKS COORDINATION

Again, the subcommittee staff came to the conclusion that the titanium program lacks coordination and direction within the executive branch of the Government. Vacillation and an apparent spirit of "let George do it," within the Air Force itself, as administered by Secretary for Air Harold E. Talbott, appears to have been a contributing factor. Air Force representatives stated that titanium will play a major role in the development of higher performance aircraft and in

guided missiles, and that it is Air Force policy to encourage its use by allowing the extra cost. However, the staff is not convinced that this policy is being followed in practice.

REDETERMINATION OF NEEDS ESSENTIAL

The Air Force representatives expressed the opinion that should several of the programs now in prototype materialize into production programs, the present goal for titanium sponge is inadequate, and that a redetermination of needs will be essential in the latter part of 1956 or early in 1957.

Better methods of collecting data for formulating projected future requirements are strongly indicated as being necessary if the sponge program is to be properly coordinated with consumption. A rapid breakthrough, and it was indicated that such might occur at almost any time, could well leave the sponge program behind and this would create a serious situation mitigating against expanded use of titanium. Part of the reluctance to design into new equipment larger quantities appears to be due to the fear that adequate quantities may not be available when needed. Planned utilization by the Army and the Navy has as one of its major determination factors the matter of quantity availability although in the case of these services price is a much greater factor than with the Air Force.

DISPOSAL OF OBSOLETE SPONGE

If fear that some of the stockpiled sponge will not stand up to present specifications is partly behind the reluctance of the Secretary of Defense and the Director of the Office of Defense Mobilization to authorize further expansion of primary sponge production, it is suggested that some of it might be sold for other industry uses where specifications are not as critical as for aircraft manufacture, even if it is necessary to take a loss, as in this way private industry could become acquainted with the material. In some fields, such as the handling of corrosive liquids, cost would not be of too great importance.

Conclusions

TECHNOLOGY ADVANCING RAPIDLY

1. The subcommittee staff is firmly of the opinion that no metal ever has made such rapid progress in winning a place for itself as has titanium; and its utilization today is, though progressing satisfactorily, in its infancy. Aluminum, magnesium, and the alloy steels went through the same difficulties but the problems were solved gradually and over a period of many years. Alloy steels still present problems. There is complete justification for great optimism about the future of titanium as the evidence shows that its technology is advancing by leaps and bounds and the most knotty problems are being satisfactorily solved almost daily.

TITANIUM A "MUST"

2. Six out of eight aircraft manufacturing companies interviewed were convinced that the expanded use of titanium is a "must" if the

United States is to maintain air supremacy. One company was somewhat less enthusiastic but still said it would have to use titanium. The eighth was ultraconservative, but apparently acts only under contract specifications set by one of the armed services. It is quite evident to the subcommittee staff that enthusiasm for the use of titanium is in direct proportion to the experience and the caliber of the research and the practical experience of each of the companies using the material.

KNOW-HOW SHOULD BE COMMON PROPERTY

3. It appears that the work the Battelle Institute is doing for the Government and industry in collecting and disseminating technical and scientific information on titanium is excellent, but the real bottleneck is the lack of means for communicating shop know-how. Each company seems to have solved certain practical problems on the shop level with which other companies still are wrestling. These are not solutions which readily can be communicated by the reading of technical papers, but have to be seen to be appreciated. General Metzger had hoped to generate intercompany visitation down to the level of the shop foreman into a general practice. The long-established habit of concealing as proprietary information certain shop know-how may further substantially retard the titanium program.

DEFENSE DEPARTMENT SHOULD LEAD THE WAY

4. The subcommittee staff feels there is an obvious lack of coordination and direction among the executive agencies and committees dealing with the titanium program. There is such a maze of redtape, routine, and timidity that an idea often becomes obsolete before it can be put into practice. Although the Department of Defense has the major interest in making titanium a success, it has not taken a strong enough lead in doing so. Efforts should be made to aid and assist in the procurement of specialized basic mill production equipment for titanium by the Department of Defense and/or its component agencies for materiel suppliers.

COST STUDIES ESSENTIAL

5. The subcommittee staff recommends that intensive study be given to lowering the cost of primary metal, and to the problem of scrap recovery, chemical machining, powder metallurgy, extrusions, integrated special facilities and greater opportunities for educating industry toward civilian uses.

CURRENT REQUIREMENT FIGURES IMPERATIVE

6. Every effort should be made by the Government to collect current requirement figures with the least possible lag and to quickly formulate them into the program. Future projections of requirements appear to have been grossly underestimated and it is imperative that those responsible for making these estimates and transmitting them to the Office of Defense Mobilization take a new look at the picture and at the limitations now placed upon the sponge program.

TITANIUM CONFERENCES

Twenty-three conferences were held over the period of April 22, 1955, and June 23, 1955, by the Minerals, Materials, and Fuels Subcommittee of the Committee on Interior and Insular Affairs of which Senator James E. Murray is chairman. The conferences were wholly informal. Those present in addition to the invited guests were members of the subcommittee staff, the consultant to Senator Murray, and Maj. Gen. Kern D. Metzger, United States Air Force (retired), consultant to the subcommittee staff and who presided at all but two of the conferences.

The purpose of the interest of the subcommittee in titanium can best be expressed in the words of General Metzger at the opening of each of the conferences. He stated that the normal problems incurred in the growth of any new structural metal had resulted in slippage in the anticipated use of titanium and that the failure of the requirements of titanium to materialize presents a serious problem to the Government in the expansion program undertaken by the Office of Defense Mobilization. He further stated that the subcommittee staff would proceed to review the present and contracted for supply of titanium, and the future demand and problems confronting industry in the use and application of the metal. The review was intended to be a constructive one designed to point up the deterrents to use and application and the efforts being made to overcome normal growth obstacles. The review also covered Department of Defense requirements for titanium—past, present, and future—with attention given to the methodology employed in computing the requirements and the adequacy thereof. Attention was given to the contracts presently in existence covering the expansion of supply and to contracts in negotiation.

The groups which were invited to send representatives were 8 aircraft companies, Aircraft Industries Association, Office of Defense Mobilization, Department of Defense, and, in addition, Army, Navy, and Air Force, General Services Administration, 2 titanium fabricating companies, 1 nationally known metallurgical consulting engineer, and 1 well-known metallurgical company which has developed a process for making titanium powder, and 1 sponge manufacturer. In addition to the above, one of the staff members of the committee visited one of the largest aircraft engine plants in the country, participating in an extensive series of conferences and shop inspections, while General Metzger visited another engine plant.

Following are highlights taken from the conversations by representatives of the different aircraft companies during the conferences. The companies will be referred to without identification.

Company A.—This company is one of the most progressive in the country and its interest in titanium is so strong that it is in the process of making a complete survey of the titanium industry, including experiences of airframe and engine manufacturers who have been working with titanium. With the survey still uncompleted, it has reached the following conclusions:

1. Great strides have been made in melting and fabricating titanium within the past 6 months.
2. The state of the art as known at their plant level has been inadequate, misleading, and obsolete.

3. Titanium in mill form, forged and extruded shapes with satisfactory physical properties is available for order.

4. Titanium alloys with physical properties exceeding present requirements for airframe use, are in the laboratory stage and can be expected for production in the near future.

5. Purchase orders will be released immediately by the company for titanium in substantial quantities and for extensive use in their new aircraft, resulting in a new weight saving of approximately 1,200 pounds per airplane.

6. Titanium can replace steel to a substantial degree in future aircraft with a highly beneficial weight saving.

This company further states that most of the information on titanium as applied to the aircraft industry which has been developed and published prior to January 1955 is virtually obsolete. Tremendous strides have been made in developing a higher quality of primary metal, alloys, fabricating and machining in the shops of the ultimate user.

Company B.—This company stressed very strongly that its designers strive very hard to save ounces of stainless steel and other metals in the design of an engine and at 1 stroke a saving of 25 percent of the total weight could be saved if titanium were put into production for the various parts that have already gone through experimental testing. Its early experience with titanium was very unsatisfactory and costly due to the quality of metal available 2 and even 1 year ago. There was a lack of experience at the vendor level and in its own machining techniques.

The heads of the various departments who had to work with titanium were very enthusiastic over its possibilities, and they are now making notable progress in solving their manufacturing difficulties and in securing a higher grade of primary metal. The staff has been informed that a large number of parts were undergoing testing under service conditions. More than 2,600 hours of testing had already been put in on these parts.

Company B has shown a very great interest in parts made of compacted titanium powder, which lends itself very readily to many items. One large piece, which required several types of machining, showed that it could be worked very easily and took a high finish. This company has a very large and efficient development shop where various parts are made and tested before being put into large production. A large and well-staffed development laboratory is also being built where new ideas can be tried and developed.

It is the unqualified opinion of this company that titanium must be used in future engines if present performance is to be exceeded.

Company C.—This company is moving rapidly toward the substantial use of titanium in the production of jet engines. Its representatives expressed belief that much of the pessimism and most of the disappointing experiences with titanium have resulted from failure to employ processes and machining techniques suitable for the characteristics of the material. It is this company's opinion that as far as aircraft engine work is concerned, titanium can be made or broken in the machine shop, depending upon the amount of intelligence devoted to it. It has its own peculiar characteristics and cannot be handled as is steel any more than steel can be handled as is aluminum.

Its representatives believe the big payoff in titanium will come in about 3 or 4 years when powerplants and airframes presently in development design will have reached the production stage.

One pound of weight saved in an engine equals 4 pounds of weight saved in the frame structure for a bomber or 2½ pounds saved in the frame structure of a fighter plane.

Company D.—This company had early disappointing experiences with titanium bolts, nuts, and fasteners. It is not pessimistic, however, and is surveying that situation again in the light of improved material.

It feels that specialized facilities are required for improvement in quality and reduction in cost. It feels that titanium is essential to high performance aircraft, at least up to Mach 4. It feels that present aluminum alloys will not satisfy requirements for high performance and that titanium and steel offer the best solution to the problem. Titanium, being the lighter in weight, is without question the most promising at this time.

Company E.—The representatives of this company are most enthusiastic over the future of titanium and are now using it extensively up to 600 pounds net weight in one of their engines. Another newer type of engine is being designed to take 1,800 pounds of titanium; while still another plane is being designed to take 2,200 pounds of titanium per engine. It is their belief that titanium must be used in these engines or they can simply forget the high performance that is demanded.

They said they could see no technical difficulties that could not be overcome with thought and work. They do not claim that they have not had any troubles but with thought and experiment a great many have been solved.

It is their opinion that 50 or 100 engines should be built and put into service as being the quickest way to determine the possibilities of the use of titanium.

This company proposes to use 4 million pounds of titanium next year, ingot weight, and possibly twice that amount the year after, which would make it the largest consumer of this material in the country.

They mentioned that one of the important benefits was the noncorrosive nature of titanium. Engine overhauling shows very little or no corrosion, while steel and aluminum parts are often badly corroded, and this company is confident that the technology in fabricating and machining has advanced to a point where titanium can and will be used in increasing quantities without undue difficulties.

Company F.—This company's representatives stated that large amounts of titanium for engines, airframes, and missiles is absolutely necessary if performance is to be improved further. They are very enthusiastic over the process of chemical machining, which is the removal of excess material by etching. This novel development should go a long way toward solving the important scrap-recovery problem, which is a big element of the cost of using titanium.

Company G.—This company felt that one of its biggest problems was welding, and the use of titanium with poor resistance to high temperature came next. This company felt that 12 percent substitution at present was the upper limit in the use of titanium for its engines, but that all future engines would have to have titanium in more or less degree.

Company H.—Company officials stated quite frankly that it was a very conservative organization and reluctant to go into even limited production on any new material. Their statement that there was not sufficient background information on performance to justify titanium being used extensively seemed to be in line with an obvious general lack of good shop information, and, judging from other information received by the subcommittee staff, was not true.

This company has been permitted to use only a small quantity of fasteners, although they have never had any trouble with the small quantity in actual use.

Most of this company's work is on Government contract, so it is under a distinct disadvantage, even though it wished to develop the use of a new material, when there is no marked desire on the part of the appropriate division of the Government to go out of its way to encourage a new material.

Aircraft Industries Association.—A representative from this association expressed the belief that expressions of optimism or pessimism regarding the potential of titanium for aircraft is in proportion to the amount of experience of each aircraft company in working with the material. This same expression was clearly brought out during the conferences with the foregoing companies.

The commercial aircraft manufacturers' thinking regarding titanium is dominated by the factor of cost. Nevertheless, substantial quantities of titanium are used in one of the most advanced commercial models.

General Metzger expressed the opinion at this meeting that the aircraft industry has the responsibility of forcefully presenting its needs for improved aircraft to the procuring services, to the industry, and to the public at large. He believed that to date the aircraft industry had not fully discharged that responsibility.

While this one conference with the Aircraft Industries Association was far from complete or conclusive, the subcommittee staff was definitely left with the impression that there existed an attitude of frustration, due, perhaps, to the magnitude of the job to be undertaken, and that AIA had not paid enough attention to the titanium picture.

Office of Defense Mobilization.—A consultant for this agency said that it was of primary importance to fully review the entire titanium supply and demand situation. He expressed concern that much of the material contracted for in early contracts was of a quality inferior to that presently being produced and said that a continuing effort should be made to renegotiate those contracts to specifications more favorable to present industry use and to the Government.

He further agreed that melting, alloying, and fabrication of the material should be given accelerated attention, and that the Department of Defense should immediately undertake a program of incorporating more of the material in defense production to enable industry to more rapidly advance the art of fabricating and working the metal.

He stated the entire situation surrounding titanium was so fluid that much of the information available to industry at the time of the conference was already obsolete, although substantial progress was being made toward furnishing titanium with acceptable physical properties, uniform quality, and in adequate quantities.

Other representatives from the Office of Defense Mobilization stated that titanium requirement figures either current or mobilization, were not used by the Department of Defense or the Office of Defense

Mobilization as a basis for establishing the 35,000-ton annual capacity goal.

The subcommittee staff also learned that a letter from the Secretary of Defense to Dr. Flemming of the Office of Defense Mobilization written in March 1955 was interpreted as a stop order on titanium expansion. Efforts by the Office of Defense Mobilization to secure clarification of the letter were without success.

The conference with the representatives of the Office of Defense Mobilization created a very strong impression that the titanium program seriously lacks direction and coordination within the executive branch of the Government. Vacillation on the part of the Air Force seemed to be a contributing factor to the chaotic situation regarding titanium.

Department of Defense.—In December 1954 the Department of Defense recommended to the Office of Defense Mobilization that no further contracting be undertaken for titanium sponge pending further requirements study. Only 22,500 tons toward the 35,000-ton goal had even received contract stature. In March 1955 the Secretary of Defense in a letter to Dr. Flemming reaffirmed the original goal of 35,000 tons annually under certain conditions. In this letter he stated that the successful development of titanium is one of the keys to air supremacy and he sees no insurmountable obstacle to the ultimate success of the program. He still believed the magnitude of the earlier forecasts of requirements was of the right order, but that commitments beyond the present contracts for 22,500 tons annually only should be made where a substantial reduction in price or improvement in quality would result.

During this conference it was brought out that a favorable report from the Materials Advisory Board on any move concerning titanium is required before a project can get anywhere with officials in the Defense Department, and so large a number of officials' O. K. is necessary, that it is only short of a miracle that anything is ever accomplished.

The Defense Department has contracted with the Battelle Institute to act in an advisory capacity and as a clearinghouse for every conceivable type of information on titanium. It seems that this information, while very valuable at all levels is generally circulated only at engineering and management levels. More interchange of ideas and shop know-how at the working level definitely is needed.

The armed services.—The conferences with representatives of the armed services left the impression that the Army is doing little or nothing to develop the use of titanium, and is simply waiting for someone else to do it. The Navy seems to be reluctant to go all out on titanium design, claiming that in many instances marginal benefits are overweighed by the high cost of titanium. In view of the great saving in weight, as shown by other witnesses, it is difficult to see why the benefits should be called marginal. The Air Force, whose sole job is to provide air defense for the country, seems to be entangled in a maze of redtape, routine, and channels through which every innovation must pass, and it is a wonder that anything new ever gets done. It sorely needs someone high enough in authority to sparkplug titanium.

Titanium fabricators.—Representatives from two of the leading fabricators of titanium were interviewed, and it was their feeling that there must be a forced coordinated and planned program for the introduction of titanium in defense products. They felt that there

has been a definite lack of coordination and direction in the program to date.

They strongly emphasized that stainless steel and aluminum were confronted in their early days with many problems equally as serious as the problems experienced with titanium. A great many of them have been overcome, but stainless steel is still a custom material produced on specialized facilities. Titanium is a custom material and probably always will be and should be produced and processed on specialized equipment rather than intermittently on equipment designed for steel.

They further raised the point of flexibility of expansion for titanium in the event of mobilization. Mobilization demands for steel could well absorb any time which is now allocated to fabricating titanium on equipment designed for steel. The result would have to be a definite decision—steel or titanium?

These representatives stated that titanium in commercially pure and alloyed forms had greatly improved in the 6 months prior to the conference. One of the large aircraft companies reported that rejection on alloyed sheet dropped from 20 percent to 2 percent in the metal received since January 1955.

They believe that the quality of titanium today is adequate for all aircraft fasteners and that a substantial tonnage could be used at an early date. There is too great a disparity, however, between fasteners selling for approximately $100 per pound and the fastener stock selling for $16 per pound.

They believe that within 5 years titanium will compete with high-strength steels in every respect. Laboratory alloy developments in several companies clearly point to this conclusion. They also believe that within 3 years the market readily will absorb between 10,000 and 20,000 tons of mill products. If this estimate materializes and the consumption curve swings sharply upward as expected, the 22,500-ton planned sponge capacity will be inadequate.

Miscellaneous.—Representatives of an established company in the business of making metal hydrides attended a conference. This company has a process for making a titanium hydride which is said to be of extremely high purity and virtually free of contaminating gases. Their product is a titanium powder which can be alloyed and then extruded or compacted as may be desired. Powder metallurgy has made tremendous strides in recent years, and in the case of titanium would seem to have a very apt application.

A metallurgist of national reputation appeared at one of the conferences and told of his early efforts in getting some work done on titanium while with the Bureau of Mines many years ago. He believes that the titanium industry has entered a new era of alloy development, which will result in improved quality and superior physical properties. He is presently working on titanium scrap reclamation, which should be of very great importance, and is also developing an electrorefining process for the prime metal which presents the possibility of continuous production at lower cost.

A producer of sponge titanium who has an application before the General Services Administration for a contract proposes to use a variation of the Kroll process which, it is claimed, will permit emergency expansion of sponge-producing facilities through the use of surplus high-cost magnesium plants. GSA has shown a strong interest in this and other processes.